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Towards sustainable energy culture in the industrial sector: introducing an interdisciplinary method for understanding energy culture in business industries

Virpi Oksman*, Francesco Reda, Sami Karjalainen, Hassam ur Rehman and Zarrin Fatima

Abstract

Background: There have been numerous research papers focusing on improving energy consumption and energy behaviour in domestic and residential contexts. However, workplaces and especially industry settings have gained less attention in scientific literature, even though the industry sector is one of the largest energy consumers in the world. This article introduces a methodological framework that utilizes the energy culture concept, to support understanding the factors that influence energy culture at business industry companies.

Methods: Building on the concept of energy culture, we introduce an interdisciplinary method, which assesses organizations' energy culture from different perspectives and recognizes the possibilities for sustainability transitions. To validate this method, the developed energy culture survey has been verified by 27 expert participants from different industry-related companies located in Finland, Italy, Switzerland, Germany France, and Austria.

Results: Our analysis highlights the need to consider diverse, interdisciplinary aspects to create a successful method for enhancing energy culture in the industrial sector. This will take into consideration human aspects, related to cognitive norms, beliefs, and aspirations, as well as to human interaction with the material world.

Conclusions: Industrial energy cultures context differs from domestic and residential contexts, and the knowledge from one context cannot be transferred to another context as such. Based on investigated studies undertaken for residential, office, and other sectors and the lessons learned, we developed a systematic method for energy culture understanding in industries. Energy managers may use it, as well as other individuals involved in energy culture issues in the industrial business sector, to evaluate the state of energy culture and engage employees towards new energy-related practices.

Keywords: Energy culture, Sustainability culture, Energy behaviour, Energy efficiency, Workplaces, Industry, Practice theory

Background

Energy behaviour and energy culture framework

In recent years, there has been a growing interest in programmes and methods aimed at changing energy behaviour at the European and global level. Today there is a consensus agreed on the urgent need for radical change in the way energy is consumed [1, 2]. Citizens,

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companies and consumers are worried about global warming and want to contribute to a more sustainable society, but they need advice, new methods and support on how to do so [3].

Energy behaviours are largely complex and shaped by many elements and factors including context, motivation and feedback [3–9]. Energy behaviour is a key term to the interdisciplinary concept of energy cultures. The behaviour in itself is affected by various factors such as values, beliefs, knowledge, societal and cultural values, the regulatory and policy environment, incentives and many others. The energy behaviour is not limited to individual behaviour only, but it is related to broader scales—how families, communities, institutions or companies behave at large [3, 10].

The behaviour of people is also an essential element when discussing energy efficiency measures. Indeed, human behaviour has a strong impact on energy consumption. How energy is consumed is the result of an individual's actions and choices. However, linking such actions and choices to energy consumption is not straightforward. People choose and act in following many factors that go beyond the sole technology or system used. Indeed, behaviours are driven by social, cultural and educational aspects that affect energy consumption and define the energy culture in the end.

The concept of energy culture has been introduced as an interdisciplinary concept, which combines different perspectives—behavioural, technical and cultural. It includes perspectives originally developed in various fields such as physics, law, sociology, economics and consumer psychology [11]. According to Stephenson et al. [10], as a conceptual framework, it aims in understanding the factors that influence energy consumption behaviour, and to help identify opportunities for behaviour change. More precisely, energy culture is a combination of material culture (i.e. technologies, buildings and infrastructure), cognitive and cultural norms, organizational energy practices, barriers and energy regulations [12].

Often people's behaviours can lead to excessive or unwanted, not useful to the purpose, energy consumption behaviours. Thus, it is therefore important for companies and society to find out whether there are some ways to turn these highly consuming behaviours into more energy rational practices with scientifically proven motivational methods: purely behavioural related, emotional or material or a combination of those elements [12]. Moreover, there are challenges related to behaviour change and to deep societal change: how to rapidly transform systems of production and consumption in ways that achieve a sustainable and equitable future. This question invites new ways of thinking about stability and change in the social world and its intersections with the physical world [11].

Reframing energy culture and energy efficiency in industrial sector

Similarly to the residential sector, the need for sustainability transformation is related to the industrial sector because a large portion of CO_2 is emitted by the industry. In general, the industrial sector can be seen as an economic branch that produces a set of raw materials, services and goods [13]. It is found that industry is responsible for emitting 122 Mtons of CO_2, whereas the residential sector emits around 86 Mtons of CO_2 in Germany [14]. Similarly, it is found that 11 Mtons of CO_2 is emitted by the industry and one Mton of CO_2 is emitted by the residential sector in Finland. However, with better energy efficiency within the industry at every level of the process, the energy consumption can be reduced and consequently the emission of CO_2 from the industrial sector and processes can be reduced. Therefore, focus on this industry sector is also essential.

A common strategy used to study energy efficiency in industrial organizations has been the quantitative measuring of certain indicators. For example, in the industrial sector, energy efficiency can be measured by the amount of energy required for production [15].

However, energy efficiency in itself is a generic term, and there is no one unequivocal quantitative measure of 'energy efficiency'. There have been considerations of if and how analytical concepts used in household research (i.e. lifestyle categories) can be adapted to the industrial sector [16]. Comparing tools and conclusions from the industry and households' sectors can be useful and some analytical tools can be picked up from one sector and adapted to another. In addition, this kind of comparisons may let us identify and discuss further, how and why different understandings of and methods for studying energy culture and improving energy efficiency appear in different contexts and whether opportunities and methods might be transferable to other sectors [16].

Energy culture has been mainly associated and researched empirically in residential and domestic contexts, while energy culture in the business and industry sector is still a less developed area of research [17]. The energy culture framework helps to make sense of how cultural formations influence energy consumption and sustainability. However, there is a need to observe energy cultures in working life contexts, including the industrial sector, which is one of the largest energy consumers in the world as mentioned above [14].

Moreover, science and technology studies have been discussing industrial efficiency in the framework of socio-technical relationships between people, organizations

and energy use in workplaces. Bull and Janda have widened energy management beyond energy managers to other employees, introducing the idea of an 'engagement gap' to support a move beyond unidirectional forms of engagement (e.g. feedback and nudging) to more socially interactive processes. Developing and using interactive, multilevel employee engagement strategies would be needed to increase energy efficiency in the industrial sector. Such strategies are not yet widely practised in organizational energy management [18].

In addition, economic sociology has considered the role of networks, technologies, behaviours in energy efficiency [19]. Although these studies have increased our understanding of energy cultures and energy efficiency, the suggestions about solutions, methods and procedures that would work in industrial and business contexts, both on the individual and organizational level, are still largely missing.

The need for an enhanced energy culture for businesses and industry

In the industrial and service sectors, energy efficiency investments are often not implemented due to a combination of various factors and barriers faced by the actors involved [1]. Even for companies that are subjected to mandatory audits, the recommendations are often only partially implemented and in some cases, only 4% of the savings potential is used [14]. In addition, in industrial companies, the organizational and behavioural energy-efficient measures are often neglected [14]. However, most employees of enterprises are also potential actors to play a role in the decision and success of implemented measure [20]. Energy behaviour in business organizations involves barriers that are not present in household settings, such as lack of a personal stake in the consequences of energy use. In addition, there is often a lack of effective feedback on the impact of actions on the organization's outcomes [17].

Some of the main challenges related to energy efficiency and energy culture transformation in an industrial environment are discussed in [21]. First, it is discussed that the magnitude of awareness about energy efficiency is still limited, that it has to be increased among each person within the hierarchy (at each level) of industry [21]. Secondly, the ways to improve energy efficiency have to be diversified and not limited to certain areas, so that they are included in every act of an individual working in the industry [21]. Thirdly, measurement and following of energy efficiency measures have to be persistent. Fourthly, the outcomes of the energy efficiency have to be integrated with the carbon reduction policy and lastly, the energy efficiency concept has to be understood and valued [21].

Within the industrial sector, there is a need for new simple methods and tools that enhance communication and increase awareness of energy efficiency and energy culture. As noted earlier, energy behaviour and behaviour change have been widely observed in residential contexts. There is less previous evidence of energy-efficient methods in workplaces, such as offices and retail and in fact, quite a few cases in the industrial contexts. Improvement in energy use behaviour and energy culture is essential within the industrial sector because it can assist in increasing the profitability, reduction of waste, reduction in energy consumption, saving in costs, better payback, better public image as a responsible entity and support in complying with various regulations [22].

The purpose of this paper is to introduce a methodology framework that utilizes the energy culture concept, to support understanding the factors that influence energy culture at business industry companies. This kind of new method aims to assist the management within the industry to improve the energy use culture among the personnel and increase awareness of energy issues as well as engage personnel to reach the energy efficiency goals and targets.

The new approach is needed to understand energy behaviours as they are a complex phenomenon that includes not only technological but also psychological, ecological and socio-cultural issues [7, 10, 12, 23]. The method is particularly developed for energy managers or equivalent who are responsible for energy monitoring and communication of energy efficiency at the company. This new method to understand energy culture in the industry sector introduced addresses different technological, psychological, ecological and socio-cultural perspectives that could lead to enhancing the energy culture towards energy efficiency and sustainable change.

The following themes form a basis for the research questions of this article: (1) what kind of method could be designed to understand current energy culture in the business and industrial context? (2) How does this method increase awareness of energy-efficient behaviours in the industrial sector?

The design of our suggested method is based on the literature review on the existing studies on energy culture in the both domestic and industrial sector.

The content of this paper is structured as follows: first part of the paper focuses on energy behaviours and energy culture concept, practice theory approach and existing studies on the field. Based on the theoretical knowledge, the following part introduces a new method to enhance energy culture within business and industries. After that, we present an expert walkthrough study on first the stage on energy culture framework in some industrial companies. Finally, we discuss our initial

findings and draw a conclusion where the applicability of the interdisciplinary energy culture method is described with a future view.

Theoretical framework: practice theory approach and contextualizing energy culture

Broadly speaking, energy-saving behaviours can be summarized into three different categories: (1) energy stock-taking behaviours and lifestyle choices, which include behaviours that are performed infrequently and at a relatively low cost, for instance, installing compact fluorescent lamps (CFLs) and weatherstripping; (2) habitual behaviours that consist of some lifestyle choices and may include, for example, laundry routines, the intention of using or not using domestic hot water (DHW), etc., habits associated with appliance use and lighting, and the frequency with which we turn off computers and other devices when not in use; (3) consumer behaviours, technology choices or purchasing decisions that require higher cost and the adoption of more energy-efficient products such as, household appliances and heating systems [24].

The above-mentioned categories imply that energy behaviours are mostly considered in domestic contexts and as individual lifestyle choices at home. In consumer studies, the concept of lifestyle is commonly referred as something that needs to be changed if we want to achieve sustainable development. It refers to various everyday choices, activities and practices that are related to energy consumption. For example, how to eat and what to eat (and drink); how to move around (by car, by bus, by bicycle, by foot, by aircraft, by boat and so forth) and where to travel, what to wear and when and where to wear it; where to live (urban, rural or in a suburb) and work [25]. However, at the workplace, the context and situation are different compared to the domestic context. Regular personnel or an individual employee may have limited opportunities to influence energy consumption or certain energy-efficient technology acquisition, even if she or he would otherwise choose sustainable alternatives. The energy consumption of the company explained as a larger phenomenon than only as an outcome of individual behaviour or lifestyle choices, and constituting of larger energy systems, technologies, practices and human behaviours, i.e. energy culture [10].

The research on energy culture and behaviour in the industrial sector has been more limited compared to the household sector [17]. According to a systematic review of the literature on energy behaviours in the industrial sector, there are several under-developed areas including businesses' energy behaviour at the individual, organizational and institutional levels; including cross-cultural comparisons [17].

Stephenson et al. [10, 13] refer to the energy culture concept consisting of distinctive knowledge, beliefs, behaviours and materials (i.e. technologies) that influence the way energy is consumed in the company. Different energy cultures can be identified between individuals, businesses, between neighbourhoods, and industries among different regions and nations [12]. The energy culture framework is mostly used to describe why or why not certain sustainability-related energy efficiency goals are or are not achieved. Often 'culture change' is needed to achieve a shift to a more sustainable future. The broader concept of sustainability cultures also offers a structured way to think about what that energy culture change might entail [11]. At an applied level, the sustainability cultures concept leads to investigations of the social world that link outcomes to cultural formations, and identification of opportunities to change those outcomes. It is an extension from its original applications to energy questions and addresses a broader range of sustainability topics besides energy including mobility and carbon [11].

The energy culture approach can be seen as related to practice theory. Practice theory in itself is related to the Actor Network Theory by Latour, which sees different agencies in the networks same time as stemming from nature, as material, technologic and human, tied with the social fabric [26]. Similarly, practice theories bring to the fore the critical role of the body and material things in all social affairs. Practice theory suggests that social structures are temporal effects that can always break down or be taken down in certain conditions. The contribution of a practice approach is to uncover that behind all the durable features of our world there is always the work and effort of someone. It also highlights that the relationship between practices and their material conditions—between 'structure and process'—is perceived as two-way traffic [27]. In addition, the practice theory approach can shed new light on the nature of knowledge and discourse. It pays attention to how various forms of knowledge (embodied, cognitive, and shared) is produced and sustained in organizations. It also studies the role of external advice [28]. Moreover, the practice theory approach focuses on the importance of physical, social and regulatory contexts, meanings, and human action [29].

Energy culture in a company is driven by many factors. On one hand, the management of the company plays an important role in defining the energy policy and setting the goals for energy consumption. On the other hand, the total energy behaviours of employees that involve many individuals with different lifestyles, values and morals and specific cultural factors determine the direction in which the energy culture is developing. According to some studies [8, 23, 30] individual attitudes and values

are less significant at workplaces, and this also applies to industry. An individual may save energy at home, but may be reluctant to sacrifice their comfort for the general good of the organization [30]. There might be little reward for saving energy at work, resulting in wasting energy behaviours in comparison to domestic users [8]. Some studies imply that personal, moral considerations, in general, are more leading in sustainable consumption issues than social dilemma considerations [31]. Whether this is also true regarding energy efficiency behaviour at workplaces is less researched, but it also implies that energy behaviours are complex. Thus, energy efficiency-enhancing methods may need to motivate employees both at the personal and social level. In some cases, employees' energy behaviour can lead to excessive energy consumption even if efficient technology is in place.

It is useful to recognize the fact that employees may not always behave optimally and not even according to their own values regarding energy issues at the workplace [32]. Thus, organizational policies and structures play an important role in guiding energy-efficient behaviours and engaging employees in enhancing common energy culture. In workplaces energy saving is rarely the central driver of the behaviour; practices and work tasks at hand are more central than saving energy in itself [7]. A significant number of studies understanding energy use and behaviours are conducted in domestic settings [4]. However, domestic, workplace, and industrial settings may vary in many ways creating very different contexts for behaviour and energy culture changes. It would be of special interest to know how contextual factors actually affect energy behaviours and how to use the information retrieved from other contexts (i.e. residential and other workplaces such as offices) to develop an effective method to improve energy culture in the business industry contexts. In addition, the practice theory approach enables us to explicate further how regulations, materials and contextual practices, behaviours and ideas which are not necessarily always conscious but embedded in norms and social structures intertwine and have consequences for energy efficiency and energy culture both at industry and residential contexts.

Contextual practices affecting energy efficiency: residential vs. industry contexts

As stated in the previous section, energy behaviours are complex and shaped by many factors [3, 11, 33]. Energy behaviour is a key term to the interdisciplinary concept of energy cultures. Energy culture is not limited to individual behaviour only, but it is related to broader scales—how families, institutions or companies behave at large.

Some studies show differences in the energy cultures and behaviour elements in the workplace and residential contexts (Table 1). This includes individual values and attitudes, social and normative environment, the effect of own behaviour on energy consumption, rewarding energy saving, and even a dress code as it affects thermal comfort and may affect energy use. Moreover, staff behaviours are central in promoting energy-efficiency strategy in any organization and industry. The effect of employees' behaviour is larger in some industries than in others [23, 34]. A clear distinction between domestic and industry context is the role of energy management, i.e. how effectively energy management activities are organized. In the industrial sector, managers and leaders play an important role in influencing the energy behaviour of

Table 1 The significance of context on energy behaviours and practices: comparison of workplace contexts with residential context

	Workplace	Residential
Individual values and attitudes	Less significant [23]	Play a big role [36]
Social and normative environment	Colleagues, clients, managers	Family, neighbours, media
Organizational policies and structures	Relevant [23]	Absent
Tasks	Focus on work tasks [34]	Focus on everyday activities (cooking, cleaning, recreation)
Ownership of building, its energy systems and electrical appliances	Not by occupants	Usually partly or completely by occupants
Energy as a priority	Rarely [23]	Not
Energy costs (economic dimension)	Covered by company	Typically paid by occupants
The number of energy costs compared to other costs	Often small, may be large in some industries	Depends on size and type of house, type of heating system, etc., in addition to income level
Effect of own behaviour on relative energy consumption	Typically small (e.g.) [34], may be large in some work tasks in some industries	May be large
Reward from decreasing energy use	Absent if no incentive programme is applied	Lower energy costs
Dress code (affects thermal comfort and may affect energy use)	Stricter	Less strict

employees and in the promoting adoption of energy-efficient organizational practices [35]

Because of the differences between these contexts, it cannot be assumed that a person always behaves similarly in both environments [37]. One example of that is that workers at the office are less interested in energy conservation than at home because they are not responsible for the energy costs in the office and may consider their consumption negligible [23, 36]. In the domestic context, energy-efficient behaviour (turning off appliances, replacing old household appliances with more energy-efficient items, etc.) can be stimulated by economic incentives and improved user comfort. Residents and house owners can gain direct economic benefits by using energy-efficient appliances [36, 38]. According to Leygue et al. [39], as the individual is directly responsible for electricity costs at home, therefore monetary saving is an important motivation. At work, the motivations might be more complex. However, it has been demonstrated that even simple interventions can result in relatively significant energy and corresponding carbon savings [23]. Even though awareness of one's energy consumption is likely to change energy consumption, at least in some contexts, in the industry context, motivations do not apply as similarly as in the domestic environment and people working for industry need to be engaged in energy-saving activities through other methods.

In the next section, we are going to study more in detail what kind of strategies or methods have been proven successful in changing energy behaviours.

Strategies for changing energy efficiency and energy behaviour in industry

As stated earlier in this article, there has been extensive research on effective strategies for changing energy behaviours in households but fewer studies at workplaces and especially in the industrial sector. Consequently, we have examined also studies undertaken for residential, office and other sectors in order to lay down the foundation of the method for changing energy behaviours and energy culture [6, 18, 24, 25, 34–36, 38, 40–52].

In the industry sector, there is a need to make energy culture and energy behaviours more sustainable. People in charge of energy-related matters need tools to assess and understand energy culture as well as methods to make improvements. Previous studies have shown that behavioural interventions are generally more effective when they are systematically planned, implemented and evaluated. Four key issues recognized were: (1) identification of the behaviour to be changed; (2) examination of the main factors underlying this behaviour; (3) application of interventions to change the relevant behaviours and their determinants; and (4) evaluation of intervention effects on the behaviour itself, its main determinants, environmental quality, and human quality of life. Interdisciplinary aspects are needed to effectively address these issues as they are psychological, ecological, technological, and socio-cultural [5].

Moreover, earlier studies suggest that social comparisons have been effective in changing energy behaviours [40]. Siero et al. studied energy consumption behaviour in a metallurgical company in the Netherlands. The employees in the first unit of the company received information about energy conservation, set energy use goals and received feedback about their conservation behaviour. In addition to that information, the second unit received information about the energy performance of the first unit. The second unit which received comparative feedback gained larger energy savings than the first unit which only received information about its performance. The comparative feedback had a larger effect than the basic behavioural change programme. The difference existed even half a year after the intervention. The change in behaviour in the second group took place with hardly any changes in attitudes or intentions [53].

Ziegler et al. [35] surveyed mid-level managers at a major infrastructure operator in the United Kingdom. The findings are likely to be relevant for large organizations (i.e. 10,000 + employees). According to the study, organizations should recognize a diversity of attitudes to energy efficiency across staff populations, and design engagement strategies to take account of these. The study suggests that organizations should avoid segmenting energy engagement campaigns based on gender, age, length of experience, and company department. They identified six aspects, which influence individuals' energy consumption behaviours in organizations: technology adoption norms, personal evaluations of the economic and environmental benefits to the organization of energy efficiency, stated intention to save energy, perceived flexibility of performance goals, awareness of energy-saving information, and perceived efficacy of small-scale energy conservation actions.

Abdelaziz et al. [40] identified three different approaches in the industrial context as the main sources of energy efficiency: (1) energy savings by management, (2) energy-saving by technologies, and (3) energy-saving by policies/regulations [40]. Thus, energy use in the context of industries is quite different compared to domestic energy use and requires equivalent concepts, approaches and methodologies. Similarly, in other sectors such as retail, the role of management and have been found as important in enhancing energy efficiency. Christina et al. [23] studied shop-floor staff in the UK and argue that the organizational policies and structures are likely to be more relevant to energy behaviour than individual

values and personal environmental attitudes. Second, the authors stressed the need for a user-centred design to manage energy effectively in stores and to make energy technology easy to operate.

Many approaches for solving energy efficiency challenges in the industry focus on applying energy-efficient technology and the role of energy management, policies and regulations. Indeed, companies often focus solely on obtaining energy-efficient technology while the importance of human behaviour and personnel is downgraded or even neglected. By engaging and educating employees and informing them about energy use at the company, their behaviour could be more energy efficient. This scenario was observed at a Swedish steel plant where reduced energy use was recorded after the energy manager had visited the production area and talked to personnel about energy [54].

To look at energy challenges from a broader perspective, in the next section we describe our method, which takes in the consideration of various interdisciplinary aspects of energy culture and pays attention to human behaviour and personnel's energy practices as a part the whole [55].

Methods

To lay down the foundation of the method for enhancing the energy culture in the industrial sector, we have investigated studies undertaken for industrial and other sectors to identify insights and lesson learnt. This has led to the creation of the main steps to consider for attempting an energy culture transformation in companies. These steps are introduced in the next section.

The energy culture survey

To understand the current energy culture and behaviours in the industry, and recognize the possibilities of sustainability transitions [11], we have designed a survey of energy culture (in Additional file 1). The survey bases on the energy culture framework, which suggests that energy behaviour can be understood at its most fundamental level by examining the interactions between cognitive norms (e.g. beliefs, understandings), material culture (e.g. technologies) and energy practices (e.g. activities) [10].

The survey has separate sections for the personnel and energy managers. The section targeted for personnel aims at identifying energy-related behaviours and practices at the workplace. The specific energy-related practises that are noted are for instance switching off appliances and lights, when they are not used and usage of sustainable modes of transport for work as well as recycling and climate-friendly meal options. Moreover, the personnel section of the survey examines the awareness of energy use at the workplace, i.e. understanding of the goals set for the energy consumption in the company and awareness of which of the workplace conditions one can control.

The energy managers section includes estimations, how the energy manager rates certain aspects of the company's energy culture such as internal communication about energy performance. In addition, in this section energy manager is asked to estimate how well the personnel working for the organization is aware of how their activities and behaviour contribute to the achievement of energy objectives and targets in general.

It is also included in the estimation if the organization does reward personnel for the energy-saving activities and behaviours. The energy manager is asked to rate how well he or she knows what the main energy consuming technology is in the company. They will also estimate the effect of barriers affecting energy-saving behaviours in the company. These barriers can relate to various factors such as lack of motivation from personnel to lack of finances to invest in energy-efficient technology to lack of efficient technology options in the market.

In the survey, energy managers are also asked to estimate what would support them to encourage energy conservation and energy efficiency in the company. They are asked to estimate what would be needed most to change the current energy culture towards energy efficiency, i.e. new ideas to engage people in energy consumption, information of successful experiences from other companies or greater support from top management.

In the first stage of the study, we organized an expert evaluation workshop with 27 participants in June 2019 in Italy. We used an expert review method [56] to assess and explore the survey and the energy culture method concept before testing it with real users later. This kind of cognitive walkthrough is a theory-based method that is readily applicable for practical assessment of a design specification or a service. Through the method, researchers get insights into what is understandable and how things make sense from the users' point of view. The participants are usually asked to identify the real user's contexts and perspectives [56].

Part of the experts participated on the site, part of them were online through the Teams-meeting system. We were going through the survey step by step, with the participants, who were asked to assess and discuss the feasibility of the energy culture method from the perspective of business industries. In this way, we were able to same time discuss and get feedback for the suggested energy culture method instantly. Expert participants filled out the energy culture framework survey online with their own mobile devices or laptops. Most of the participants were energy efficiency experts from companies or organizations with

over 250 employees in Finland, Germany, Italy, Switzerland and France.

Formulation of evaluation framework—energy culture pillars

To analyse the results of the survey, five pillars (Table 2) were formed by the authors. They are based on the scientific literature [10] and provide a foundation to understand the current energy culture within the company and identify the sustainability transformation possibilities. The pillars are described as following:

(1) awareness of technologies; (2) specific cultural aspects; (3) current energy practices in the company; (4) external factors (e.g. community thinking, EU and national regulatory framework in place); and (5) effect and perception of barriers mapped.

(1) The pillar awareness of technologies refers to a person's interaction with material culture. Material culture can be understood as buildings, furnishings, technologies, etc. To be more specific, technologies themselves act to influence behaviours and expectations, so that social practices and technological artefacts shape and are shaped by one another [11]. This pillar includes questions, how the personnel is aware of the material culture around them such as technologies to control temperature or lighting at the workplace in general. In addition, it includes questions; is the personnel aware of the usage of standby mode of appliances like laptops, energy use of process machine, etc., and do they understand or pay attention to it. For management, this means for instance being aware of what is the most energy consuming technology in the company overall. (2) The pillar specific cultural habits, user beliefs and aspirations, motivations, lifestyle and social class refer to characteristics of cultural groups and their interactions with cognitive norms. Using Bourdieu's term 'habitus`, i.e. socialized tendencies that guide behaviour and thinking and cognitive norms strongly influence people's choices and the practices that they undertake [11]. Behaviour at the workplace can reflect these cognitive norms of cultural groups or lifestyles. As an example, the survey studies practices such as choosing vegan or vegetarian options for a meal, car sharing, use of electric vehicles or purchasing local products. (3) Current energy practices pillar at company combines elements that can be systemically understood as interactions between individual, social and institutional behaviours. It consists of questions for personnel regarding the practices they do regularly to decrease emissions or save energy, such as switching off lights, putting devices on standby mode, etc. (4) The pillar external factors considers larger societal factors such as community thinking and EU and national regulatory framework in place. These may not be visible in the everyday practices for personnel, so that they would need to think about the regulations in their everyday work tasks but are more connected to decisions management makes so that the company policy includes a commitment to energy efficiency regulations and recommendations at municipal or state level. (5) The effect and perception of barriers mapped—pillar points to particular challenges perceived from the point of energy management. These may refer to several cross-disciplinary problems such as lack of information about energy-efficient behaviours in the workplace, lack of motivation to save energy, lack of available energy-efficient technologies or lack of resources or lack of educated personnel [16, 54].

Table 2 Maturity matrix scoring

	Answer score 1–2	Answer score 3–4	Answer score 4–5
Maturity of pillar	Low	Medium	High

Maturity matrix

Each question in the energy culture survey (Additional file 1) is related to one of the five pillars described above. In the survey, the respondent chooses whether she or he agrees or disagrees with the suggested statements regarding energy-related matters in their company (1 = strongly disagree, 5 = strongly agree, 0 = does not apply). The five-point Likert scale was selected as it is most often used to measure attitudes of the general public [57, 58]. In turn, each answer has a score, and depending on the selected answer, the final score of the pillar would be either low, medium or high (Table 2).

As a result, the use of the Likert scale allows evaluation of pillars and questions and which ones have a high, medium or low level of maturity. For instance, is the awareness of technologies perceived as good or does the personnel do certain things regularly to save energy. The survey is then able to give responses to which aspects of energy culture need to be improved in the company. It may be used by management or energy managers to evaluate the state of energy culture maturity and to address challenges of energy culture. It can be complemented with practical materials such as educational materials and recommendations to improve or keep the maturity of specific energy culture pillars high in order to enforce the energy efficiency corporate policy towards behavioural change.

Efficiency opportunities may arise when one specific energy culture pillar is not mature enough and, therefore, not in line with other energy culture pillars [12]. Based on the outcome of the survey and scoring in the maturity matrix, the survey then suggests a set of actions that could be undertaken to support the energy culture

transformation or alternatively, keep the maturity level of the matrix at a high level. The action recommendations are provided for both survey sections: energy manager and employees. The lower the score in any pillar, the more action recommendations to improve the situation will be given. These actions can include various recommendations and materials, such as social media platforms for the personnel allowing them to share their ideas about energy saving, contests among personnel or choosing new systems for low energy consumption or educational materials such as training videos.

Results

Suggested interdisciplinary method to energy culture transition in industries

In order to create a method for enhancing the energy culture in the industrial sector, we have investigated studies undertaken for residential, office and other sectors to identify lesson learnt and insights to lay down the foundation of the method. As a result, we have designed an interdisciplinary method (Fig. 1) to understand the current situation and the main steps to consider for attempting an energy culture transformation in industrial companies.

This method can be used by energy managers as a self-assessment tool of how he or she is performing in the task. It suggests practical actions to proceed with energy efficiency and energy behaviours. In addition, it should be pointed out that it is necessary to make the method as socially interactive and engaging process as possible so that it is useful for both personal and energy management [18]. Moreover, fit for purpose communication about results and tailoring the method suitable for each context or company is essential [59].

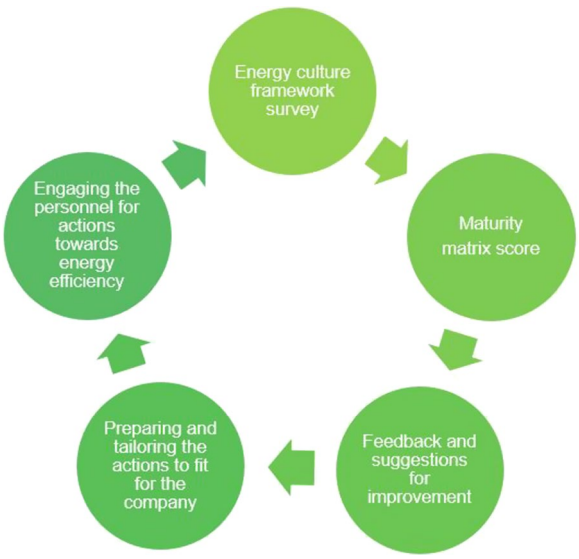

Fig. 1 Interdisciplinary concept to understand and enhance energy culture transition in the industrial companies

Energy culture survey walkthrough findings

To increase awareness of energy-efficient behaviours in the industrial sector, the first step would be to identify the behaviours to be changed and examine the motivation behind them [5]. For this purpose, we organized an expert walkthrough and demonstrated the first step of the proposed energy culture method, i.e. energy culture survey. During the expert walkthrough, the survey and the energy culture method were introduced to the participants, including the maturity matrix score and preliminary recommendations step by step.

This relatively limited study suggested that, according to the expert evaluation, the tool is usable for the industrial companies to assess their energy culture and to pinpoint the challenges of the current state of the energy culture. With this methodology, we were able to set the result matrix and show how find out the status of each company's energy culture pillars and suggest areas for improvement. The participants experienced the platform to be an easy and convenient tool for filling out energy culture survey. The experts responded to questions, such as sustainable mobility and the most popular actions for saving energy. Figure 2 shows the outcome of the survey carried out on the persons working in the industry and the things they do to reduce energy consumption. Figure 3 shows the challenges and barriers faced by the energy manager that are affecting the energy efficiency in the industry.

Using the survey, we were able to address the major challenges of the companies' energy culture from the personnel perspective, including the behaviours to be changed and some motivations behind them. Moreover, according to the experts' feedback energy saving is not always possible in company contexts as the users cannot control certain technical equipment. For instance, they cannot decrease room temperature or influence choosing of renewable energy providers or sustainable machines for their companies. In this study, switching off lights and recycling were recognized as the most common and convenient ways of saving energy by employees in industrial companies. There are also not always sustainable options available; for instance, teleworking or car-sharing possibilities, even if wanted. Participants also reflected how the material culture, i.e. available technologies or just cultural patterns were influencing their energy consumption at the workplace:

> *"I'm generally careful to my energy consuming. Sometimes this doesn't happen because of difficul-*

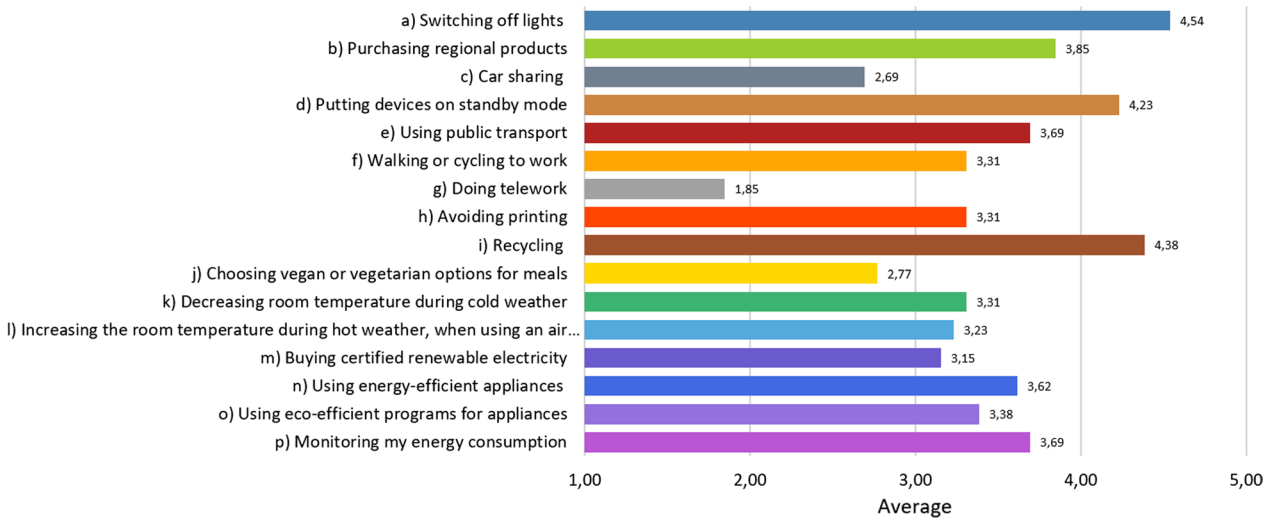

Fig. 2 An example question of energy culture study in industry for personnel. Which of the following things do you regularly do to decrease emissions or save energy? (1 = never, 5 = very often)

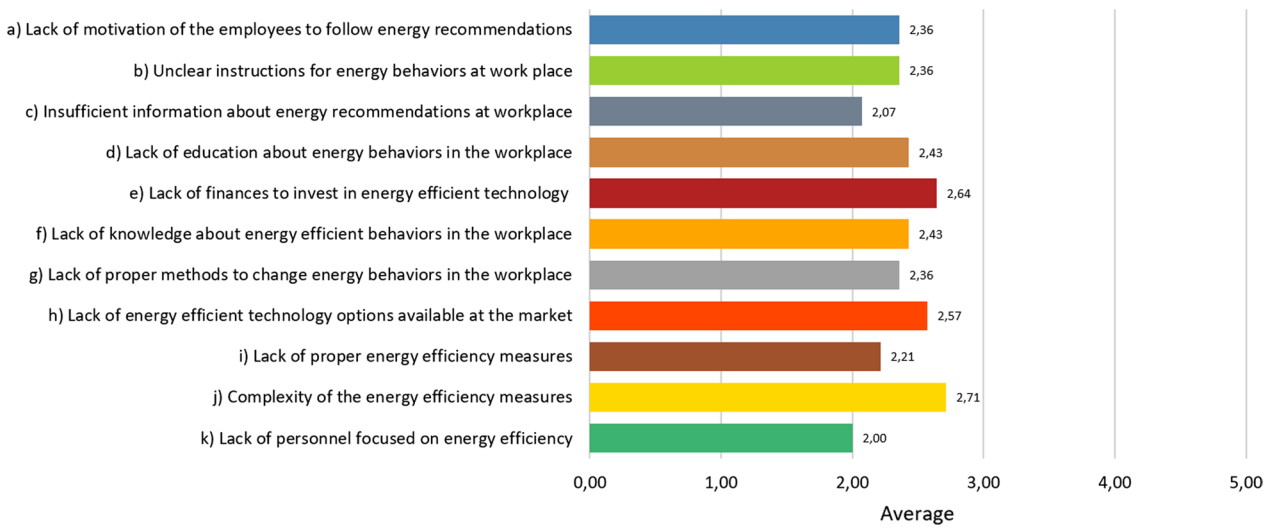

Fig. 3 An example question of energy culture study in industry for energy managers. Rate the effect of barriers affecting energy consumption in your company (1 = not significant at all, 5 = very significant)

ties in terms of time or technical impossibility to care energy matters. For example: difficulties to find sharing mobility options, renewable energy providers, option to choose telework"

Cultural habitus or a lifestyle may also affect some of the choices more than others:

"Personally, I do not use air condition very often. I do not own a car and walk and use public transport a lot. On the other hand, I do not really pay attention to the energy efficiency of household appliances."

In general, the experts evaluated that it is challenging to engage employees to save energy, but this kind of method and tool can make it easier for energy managers and also for personnel for self-evaluation. It can support identifying the areas and behaviours to be changed, improve communication within the company and raise awareness of energy efficiency among employees and suggest practical actions for improvement.

However, some of the experts also raised the conversation about whether personnel would be willing to

share such details about their energy consumption and lifestyle in a company survey.

Discussion

Earlier studies have addressed that it is important to approach energy efficiency from a new perspective, using analytical tools that can contribute new understandings or questions as to why a particular barrier is perceived as important in a company. In addition to analysing a company's culture and understanding the context in which energy efficiency goals discussed, is important in order to take industrial energy efficiency a step further [60]. As noted earlier in the paper, the human factor—the behaviour of people and larger energy culture is also an essential element when discussing energy efficiency measures—it is not only about technologies, but in practice theory terms—about different agencies in the networks at the same time as stemming from nature, as material, technologic and human, tied with the social fabric [26, 60].

Therefore, we have introduced an interdisciplinary method to understand and enhance the current energy culture in the industrial sector. Our studies extend the previous research on energy behaviours and energy culture as the proposed method aims to understand the challenges in the business industry context, aiming in to understand and improve companies' energy cultures. In addition, the method captures the energy manager's and employees' points of view while also assessing the status of energy culture within the organization as a whole. Moreover, based on the scientific literature referred in this paper, the proposed energy culture method moves forward by suggesting also actions that have been proven efficient in different contexts [38].

Thus, most employees of industrial enterprises are also potential actors to play a role the success in implementation of energy efficiency meters and sustainability if they are engaged in the activities. However, linking such actions and choices to energy consumption is not straightforward and it cannot be guaranteed. People choose and act in accordance with a number of factors that go beyond the sole technology, organization or system used. Behaviours are driven by various social, cultural and educational aspects that affect energy consumption and define the energy culture in the end.

Our empirical study example limits at the first stage of the energy culture framework: energy culture survey study and considers only the energy experts' views. Since we have not conducted more extensive empirical research at this stage, we cannot say how difficult it is to engage personnel on the energy savings in the long run in real-life contexts and whether the new method of energy culture will actually change energy practices. The next stage, implementation of actions demands time and dedication by the management and cooperation of all employees in any organization. Adoption of these kinds of new methods may also bring challenges to some of the everyday practices, workflows and processes.

However, the communication about energy culture to raise awareness of energy efficiency is also crucial in achieving results, as it has been shown in earlier studies. Building on that assumption, it crucial to treat employees as active participants, rather than mere passive targets of information, actions and strategies. In fact, previous research in the energy field suggests that employee engagement is much more important than is currently known or studied [18].

The proposed energy culture method is generic and may need to be adapted to fit, for example, different industry sectors or for companies of different sizes, depending on how much and what kind of resources they have. Often these kinds of new methods bring challenges to some of the everyday workflows and processes, for instance, who will engage with employees and follow, and administer such tools and methods [62]. Thus, the energy culture and energy efficiency tools must be practical, fast and easy to use [44].

Conclusion

There are several factors, which differentiate the energy cultures and behaviours in workplace contexts and residential contexts, as described earlier in this paper. This includes among other things individual values and attitudes, social and normative environment, the effect of own behaviour on energy consumption, and rewarding from energy saving.

We have developed an interdisciplinary method for understanding energy culture in industries. Energy managers may use it, as well as other individuals involved in energy efficiency in the industrial business sector, to evaluate the state of energy culture maturity and engage employees towards new energy-related practices.

Earlier, energy use in the industrial sector has been researched less compared to the household sector. It would be of interest to know, whether developing new tools also would raise awareness about the importance to recognize energy-saving potential in the industry sector. However, the challenge remains, how the industrial companies are able to adopt and make use of these kinds of new tools and enhance their energy culture. Although easy-to-use, new tools will also bring additional challenges to some of the everyday workflows and processes. For instance, somebody needs to follow the energy culture maturity development and administer and organize actions to engage personnel to enhance the energy culture. The full benefit of this kind of service will be

realized when it is systematically used as a part of company workflows and sustainability strategies.

The next steps of our study will focus on practices for improving energy cultures in companies. These will also include a demonstration of the practical actions described in our method for the selected companies. The next phases of the study will include the energy culture framework method to various industries and companies in Germany, Austria, Italy, France, Switzerland and Finland to also study the possible differences of energy cultures among these countries and different types of industrial companies.

Abbreviations

CFL: Compact fluorescent lamps; CO_2: Carbon dioxide; DHW: Domestic hot water; Mtons: Metric tons; SME: Small and medium enterprises; UK: United Kingdom.

Supplementary Information

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Additional file 1. Energy culture survey questions.

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Authors' contributions

The idea of the research paper was generated by VO, FR and SK. VO created the survey and carried out the expert walkthrough with FR. FR and SK created the first framework version of energy culture pillars. VO structured the paper and wrote most of the chapters and answered the questions to the reviewers in the revised manuscript and edited the revised manuscript for submission. HUR helped with editing and with some of the questions of the reviewers and wrote some parts of the manuscript. ZF contributed, especially to the maturity matrix section. All the authors read and approved the final manuscript.

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Availability of data and materials

The research materials are not available publicly because of company confidentiality.

Declarations

Ethics approval and consent to participate

All necessary participant consent has been obtained. GDPR and data security rules were followed.

Consent for publication

Yes.

Competing interests

The authors declare that they have no competing interests.

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References

1. EU Economy Final Report (2015) Energy Efficiency-the first fuel for the EU Economy FINAL REPORT covering Buildings, Industry and SMEs. How to drive new finance for energy efficiency investments, pp 1–126
2. Dahlbolm B, Greer H, Cees E, Jonkers R (2009) Changing energy behaviours. Intelligent Energy Programme Europe, Madrid, pp 1–96
3. Littleford C, Ryley TJ, Firth SK (2014) Context, control and the spillover of energy use behaviours between office and home settings. J E 40:157–166
4. Lopes MA, Antuned CH, Martin N (2012) Energy behaviours as promoters of energy efficiency: a 21st century review. Renew Sustain Energy Rev 16:4095–4104
5. Steg L, Vlek C (2009) Encouraging pro-environmental behaviour: an integrative review and research agenda. J Environ Psychol 29:309–317
6. Faraqui A, Sergici, S, Sharif, A (2010) The impact of informational feedback on energy consumption—a survey of the experimental evidence. Energy 35(4):1598–1608
7. Stikvoort B, Juslin P, Bartusch C (2017) Good things come in small packages: is there a common set of motivators for energy behaviour? Energy Effic 11:1599–1615
8. Yun R, Scupelli P, Aziz A, Loftness V (2013) Sustainability in the workplace: nine intervention techniques for behavior change. In: 8th International conference, Persuasive Technology, Sydney, pp 253–265
9. Susan M, van Stralen MM, West R (2011) The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. https://doi.org/10.1186/1748-5908-6-42
10. Stephenson J, Barton B, Carrington G, Gnoth D (2010) Energy cultures: a framework for understanding energy behaviours. Energy Policy 38:6120–6129
11. Stephenson J (2018) Sustainability cultures and energy research: an actor-centred interpretation. Energy Res Soc Sci 44:242–249
12. Stephenson J, Barton B, Carrington G, Gnoth D (2015) The energy cultures framework: exploring the role of norms, practices and material culture in shaping energy behaviour in New Zealand. Energy Res Soc Sci 7:117–123
13. Iammarino S, McCann P (2013) Multinationals and economic geography: location, technology and innovation. Cheltenham, Glos, UK
14. International Energy Agency (IEA) (2018) CO_2 emissions from fuel combustion. https://www.iea.org/countries/germany. Accessed 11 Jan 2021
15. Patterson MG (1996) What is energy efficiency?: Concepts, indicators and methodological issues. Energy Policy 24(5):377–390
16. Palm J (2009) Placing barriers to industrial energy efficiency in a social. Energ Effic 2:263–270
17. Andrews RN, Johnson E (2016) Energy use, behavioral change, and business organizations: reviewing recent findings and proposing a future research agenda. Energy Res Soc Sci 11:195–208
18. Bull R, Janda KB (2018) Beyond feedback: introducing the 'engagement gap' in organizational energy management. Build Res Inf 46(3):300–315
19. Woolsey Biggart N (2007) Economic sociology and the social problem of energy inefficiency. Am Behav Sci 50:1070–1087
20. Bull R, Janda KB (2018) Beyond feedback: introducing the 'engagement gap' in organizational energy. Build Res Inf 46(3):300–315
21. Grueneich DM (2015) The next level of energy efficiency: the five challenges ahead. Electr J 28(7):44–56

22. Gopalakrishnan B (2013) Opportunities and challenges in industrial energy efficiency. West Virginia Department OF Commerce, West Virginia
23. Christina S, Dainty A, Daniels K, Waterson P (2014) How organisational behaviour and attitudes can impact building energy use in the UK retail environment: a theoretical framework. Archit Eng Des Manag 10:164–179
24. Ehrhardt-Martinez K, Donnelly K, Laitner J (2010) Advanced metering initiatives and residential feedback programs: a meta-review for household electricity saving opportunities. American Council for an Energy-efficient Economy. American Council for an Energy-efficient Economy, Washington, DC
25. Jensen M (2007) Defining lifestyle 4, 2007. Environ Sci 4(2):63–73
26. Latour B (1996) On actor-network theory: a few clarifications. Soziale Welt 47(4):369–381
27. Nicolini D (2012) An introduction. In: Practice Theory, Work, and Organization, Oxford University Press, Oxford, pp 1–19
28. Hampton S (2019) Making sense of energy management practice: reflections. Energy Effic 1(12):1473–1490
29. Palm J (2014) The meanings of practices for energy. Sci Technol Stud 27(2):72–92
30. Nisiforou O, Poullis S, Charalambides A (2012) Behaviour, attitudes and opinion of large enterprise employees with regard to their energy usage habits and adoption of energy saving measures. Energy Build 55:299–311
31. Wringer K (2017) Sustainable consumption dilemmas. Sustainability 9:942
32. Karjalainen S (2016) Should we design buildings that are less sensitive to occupant behaviour? A simulation study of effects of behaviour and design on office energy consumption. Energy Effic 9:1257–1270
33. Darby S (2006) The effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays, environmental change institute, University of Oxford, Oxford, pp 1–21
34. Coleman MJ, Irvine KN, Lemon M, Shao L (2013) Promoting behaviour change through personalized energy feedback in offices. Build Res Inf 41:637–651
35. Zierler R, Wehrmeyer W, Murphy R (2017) The energy efficiency behaviour of individuals in large organisations: a case study of a major UK infrastructure operator. Energy Policy 104:38–49
36. Bird S, Legault L (2018) Feedback and behavioral intervention in residential energy and resource use: a review. Curr Sustain Energy Rep 5:116–126
37. Karjalainen S (2007) The characteristics of usable room temperature control. PhD Thesis, Helsinki University of Technology, Espoo, Finland
38. Fischer C (2008) Feedback on household electricity consumption: a tool for saving energy? Energy Effic 1:79–104
39. Leygue C, Ferguson E, Spence A (2017) Saving energy in the workplace: why, and for whom? J Environ Psychol 53:50–62
40. Abdelaziz E, Saidur R, Mekhilef S (2011) A review on energy saving strategies in industrial sector. Renew Sustain Energy Rev 15:150–168
41. Abrahamse W, Steg L, Vlek C, Rothengatter T (2005) A review of intervention studies aimed at household energy conservation. J Environ Psychol 25:273–291
42. Delmas M, Fischlein M, Asensio O (2013) Information strategies and energy conservation behavior: a meta-analysis of experimental studies from 1975 to 2012. Energy Policy 61:729–739
43. Javied T, Rackow T, Franke J (2015) Implementing energy management system to increase energy efficiency in manufacturing companies. Procedia CIRP 26:156–161
44. Delmas MA, Lessman N (2014) Saving power to conserve your reputation? The effectiveness of private versus public information. J Environ Econ Manag 67:353–370
45. Johnson D, Horton E, Mulcahy R, Foth M (2017) Gamification and serious games within the domain of domestic energy consumption: a systematic review. Renew Sustain Energy Rev 73:249–264
46. Huebner G, Cooper J, Jones K (2013) Domestic energy consumption—what role do comfort, habit, and knowledge about the heating system play. Energy Build 66:626–636
47. Gordić D, Babić M, Jovičić N, Šušteršič V, Končalović D, Dubravka J (2010) Development of energy management system—case study of Serbian car manufacturer. Energy Convers Manag 51:2783–2790
48. Kannan R, Boie W (2003) Energy management practices in SME—case study of a bakery in Germany. Energy Convers Manag 44:945–959
49. Karlin B, Zinger J, Ford R (2015) The effects of feedback on energy conservation: a meta-analysis. Psychol Bull 141:1205–1227
50. Uitdenbogerd D, Egmond C, Jonkers R, Kok G (2007) Energy-related intervention success factors: a literature review. In: Proceedings of the ECEEE 2007 Summer Study: Saving Energy- Just Do It, Cote d'Azur, France, vol 1, no 4, pp 1857–1853
51. Staddon S, Cycil C, Goulden M et al (2016) Intervening to change behaviour and save energy in the workplace: a systematic review of available evidence. Energy Res Soc Sci 17:30–51
52. Thomsen J, Lappegard HÅ, Lund GÅ (2014) Interventions on energy behaviour in non-residential buildings—a literature review. SINTEF Academic Press, Oslo, Norway, pp 1–21
53. Siero F, Bakker A, Dekker G, Van den Burg M (1996) Changing organizational energy consumption behaviour through comparative feedback. J Environ Psychol 16:235–246
54. Johansson MT, Thollander P (2018) A review of barriers to and driving forces for improved energy efficiency in Swedish industry—recommendations for successful in-house energy management. Renew Sustain Energy Rev 82:618–628
55. Johansson MT (2015) Improved energy efficiency within the Swedish steel industry—the importance of energy management and networking. Energy Effic 8(4):713–744
56. Bertelsen OW (2004) The activity walkthrough: an expert review method based on activity theory. In: NordiCHI '04 proceedings of the third Nordic conference on human–computer interaction, Tampere, pp 251–254
57. Joshi A, Saket K, Satish C, Pal D (2015) Likert scale: explored and explained. Br J Appl Sci Technol 7(4):396–403
58. Weijters B, Cabooter E, Schillewaert N (2010) The effect of rating scale format on response styles: the number of response categories and response category labels. Int J Res Mark 27(3):236–247
59. Pasini D, Reda F, Häkkinen T (2017) User engaging practices for energy saving in buildings: critical review and new enhanced procedure. Energy Build 148:74–88
60. Palm J, Thollander P (2010) An interdisciplinary perspective on industrial energy efficiency. Appl Energy 87:3255–3261
61. Axon S et al (2018) The human factor: classification of European community-based behaviour change initiatives. J Clean Prod 182:567–586
62. Oksman V, Kulju M (2017) Developing online illustrative and participatory tools for urban planning: towards open innovation and co-production through citizen engagement. Int J Serv Technol Manag 6(5):445

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